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Kishi et al.

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(54) **CRYSTAL UNIT AND METHOD OF MEASURING CHARACTERISTICS OF THE CRYSTAL UNIT**

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(51) **Int. Cl.**

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H01Q 1/22	(2006.01)
H03B 5/06	(2006.01)
H03B 5/36	(2006.01)
H01Q 9/42	(2006.01)
G06K 19/073	(2006.01)

(52) **U.S. Cl.**

CPC ***G01R 23/02*** (2013.01); ***H01Q 1/22*** (2013.01); ***H01Q 9/42*** (2013.01); ***H03B 5/06*** (2013.01); ***H03B 5/32*** (2013.01); ***H03B 5/362*** (2013.01); *G06K 19/073* (2013.01)

(58) **Field of Classification Search**

CPC G01R 31/00; H01Q 1/22; H01Q 9/42; H03B 5/32; H03B 5/06; G06K 19/073

USPC .... 73/718; 331/158, 116 R, 116 FE, 66, 331/36 C; 343/700 MS

See application file for complete search history.

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(57) **ABSTRACT**

A crystal unit may include a crystal piece, an excitation electrode configured to excite the crystal piece, a case configured to accommodate the crystal piece, an external electrode formed in the case and configured to be electrically connected to the excitation electrode, and an antenna formed in the case and configured to be electrically connected to the external electrode.

7 Claims, 7 Drawing Sheets

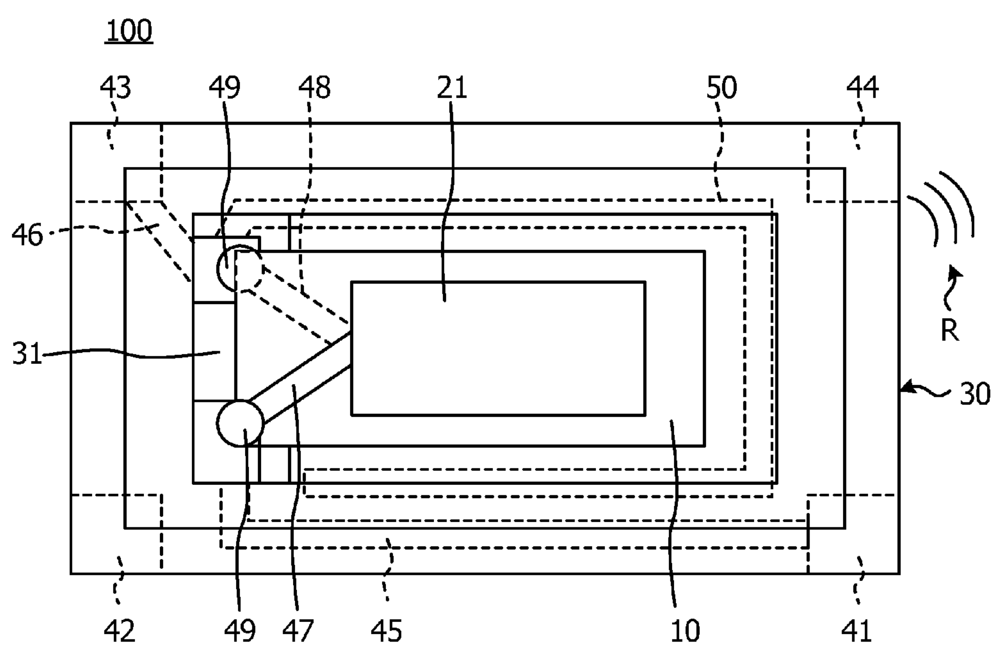


FIG. 1A

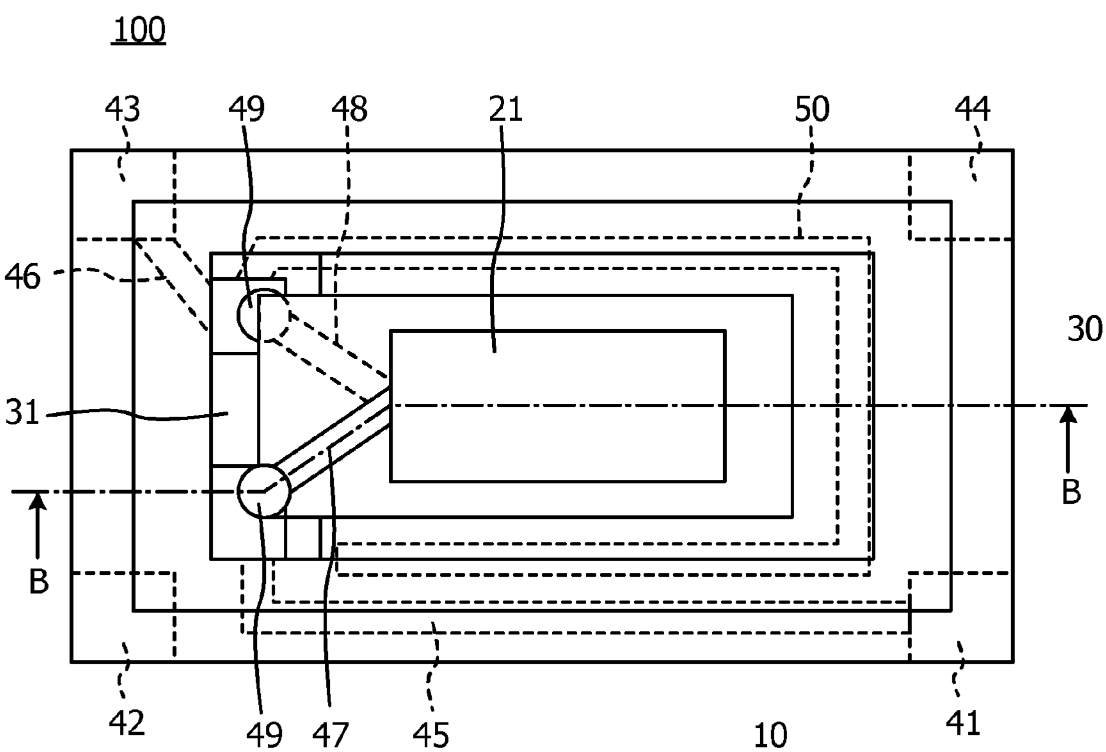

100
43
49
48
21
50
44
46
30
31
B
B
42
49
47
45
10
41

FIG. 1B

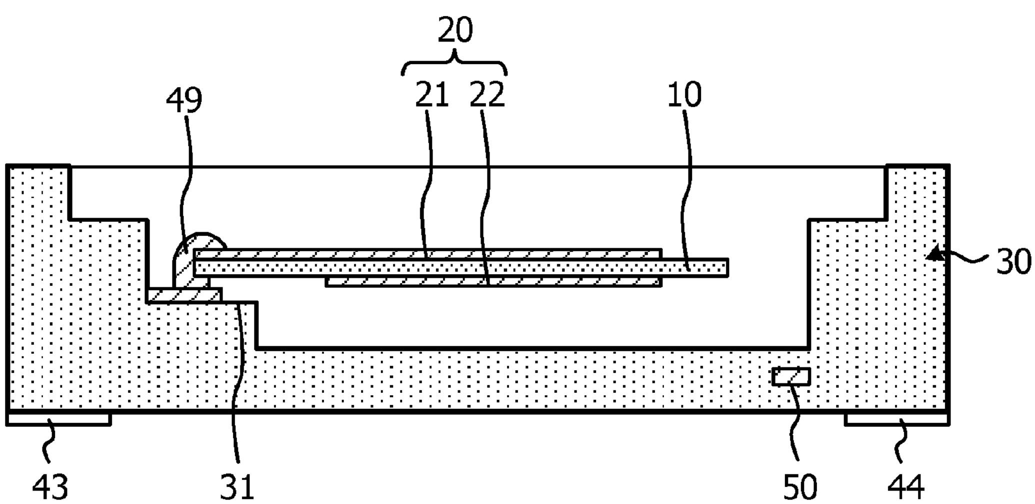

20
49
21
22
10
30
43
31
50
44

FIG. 2

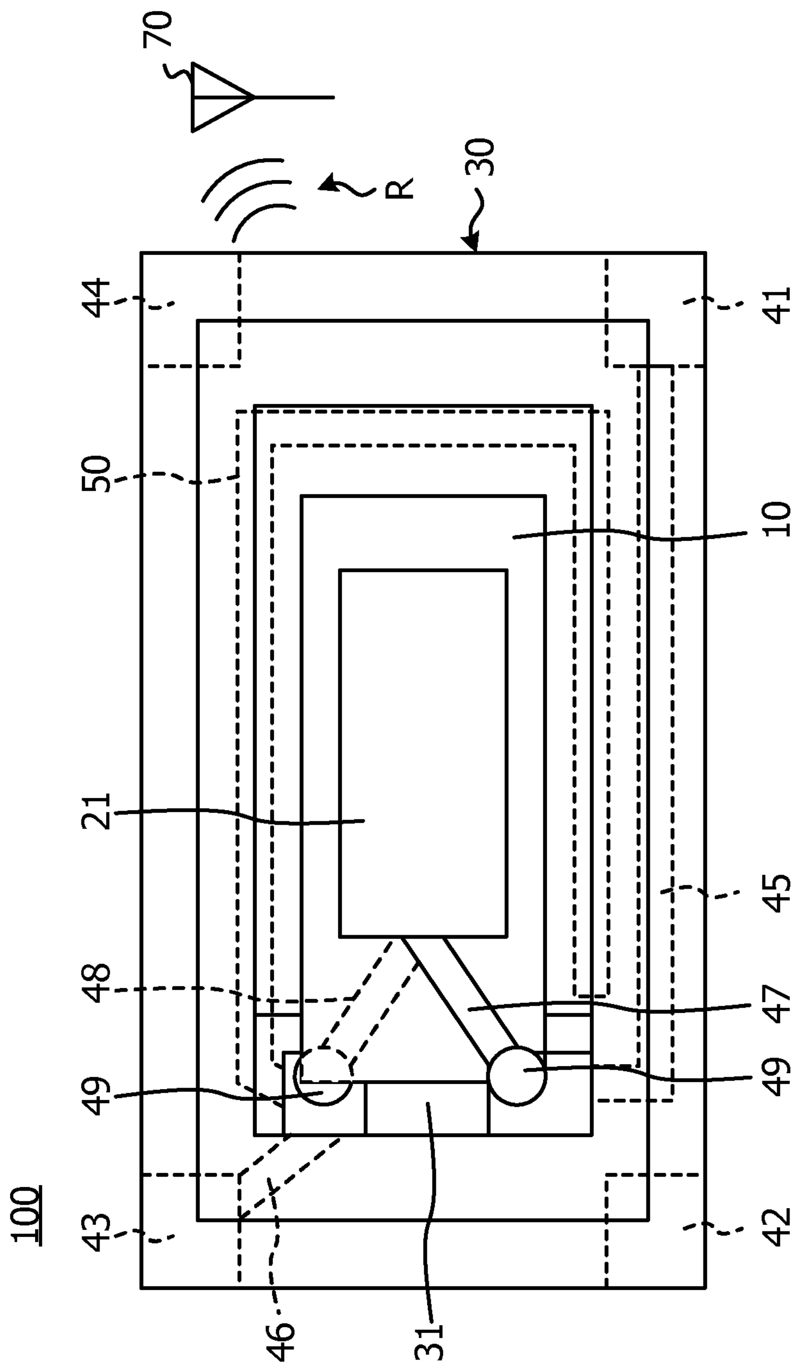


FIG. 3

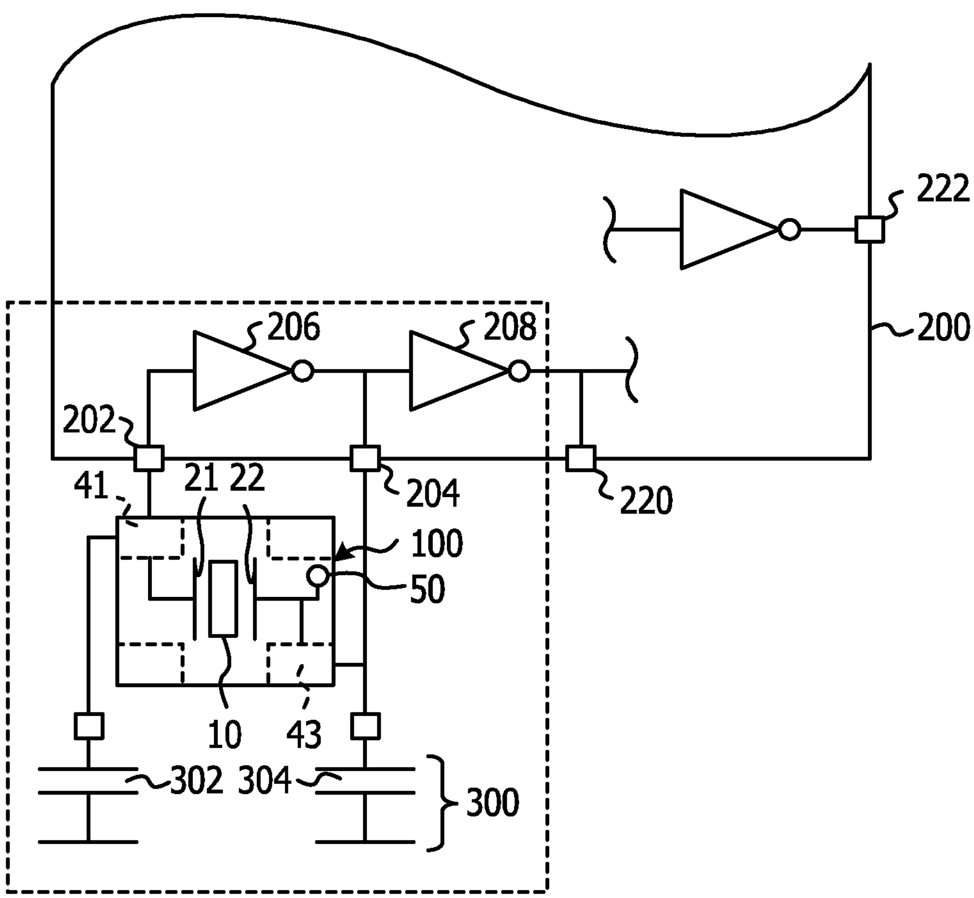


FIG. 4

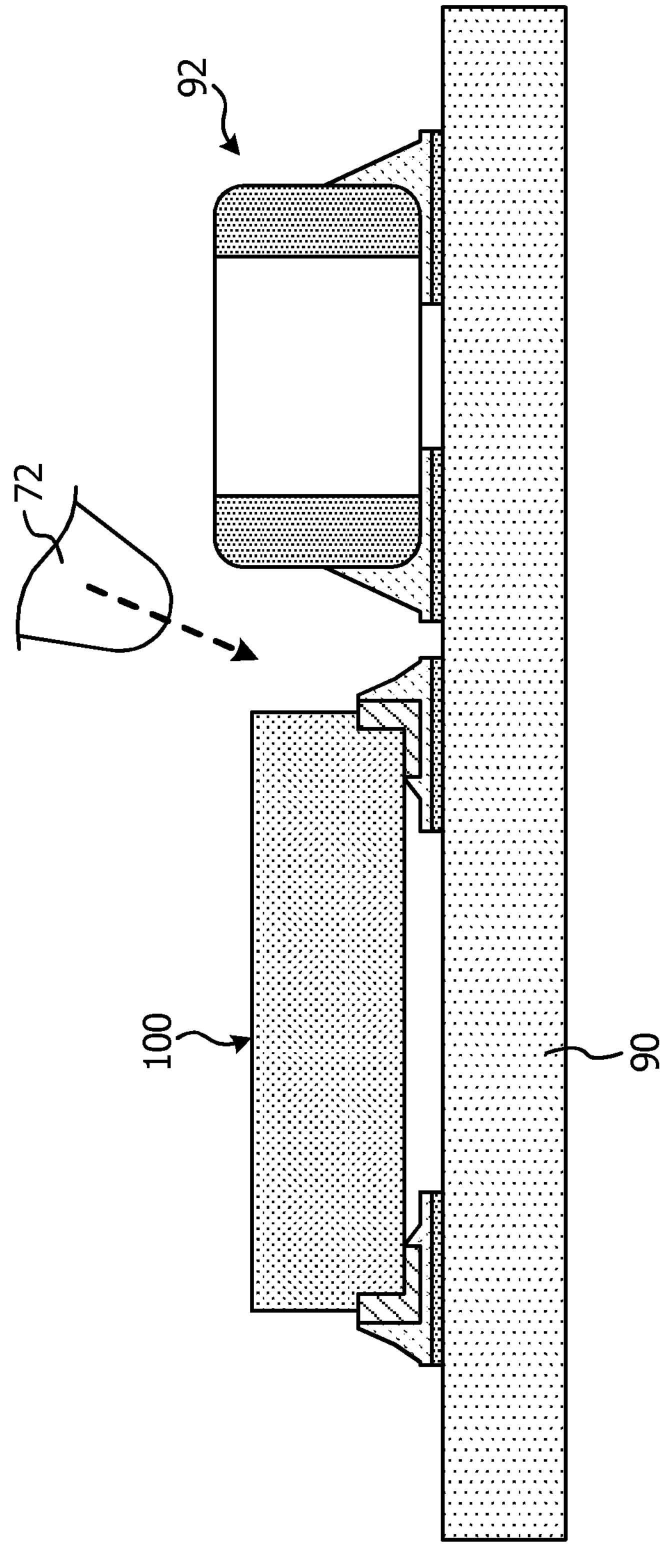


FIG. 5A

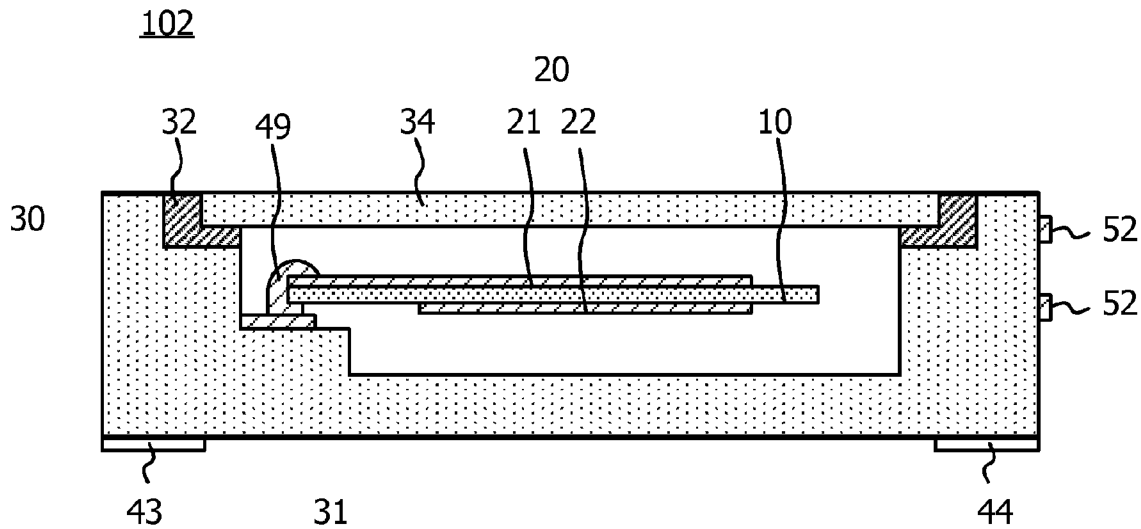


FIG. 5B

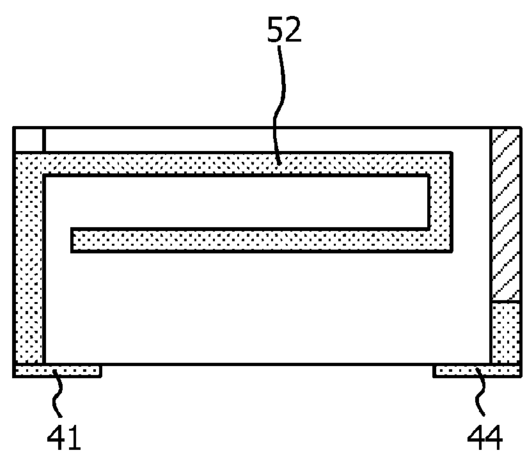


FIG. 6A

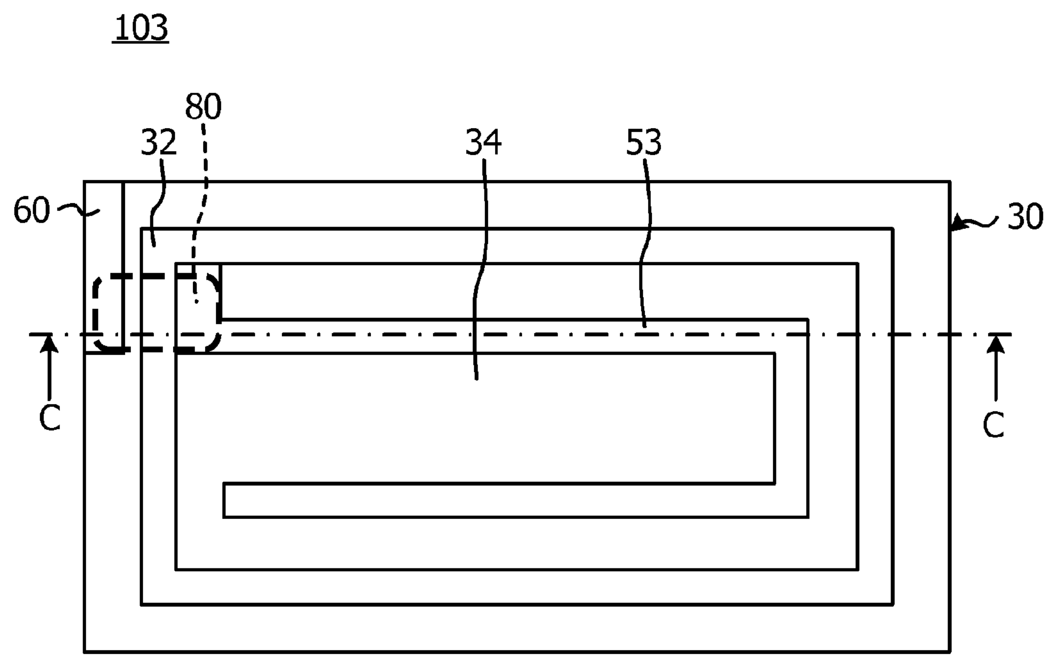
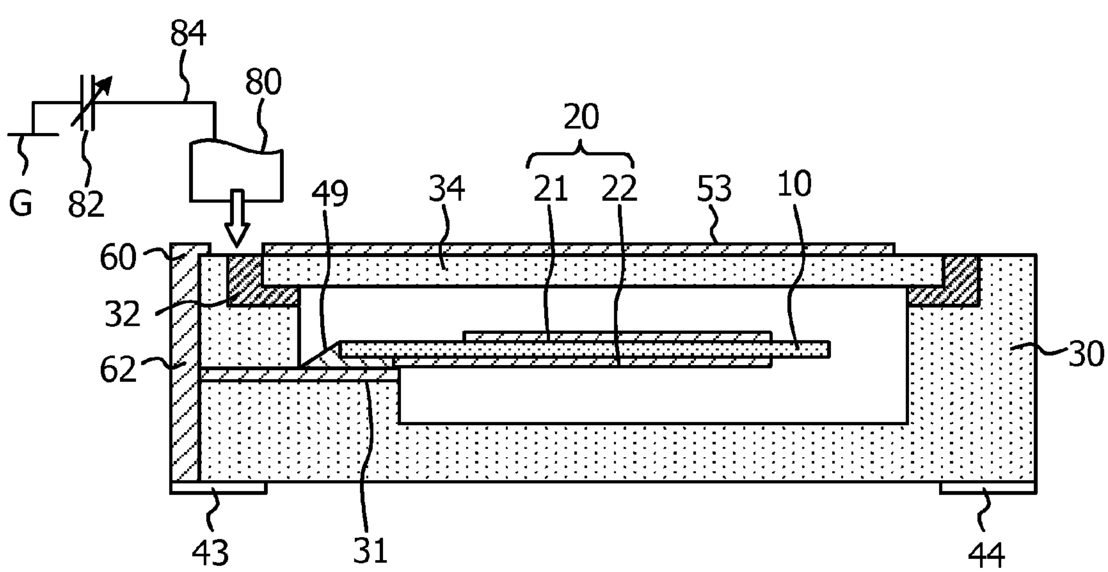

103
80
32
34
53
60
30
C
C

FIG. 6B


84
80
20
G
82
49
34
21
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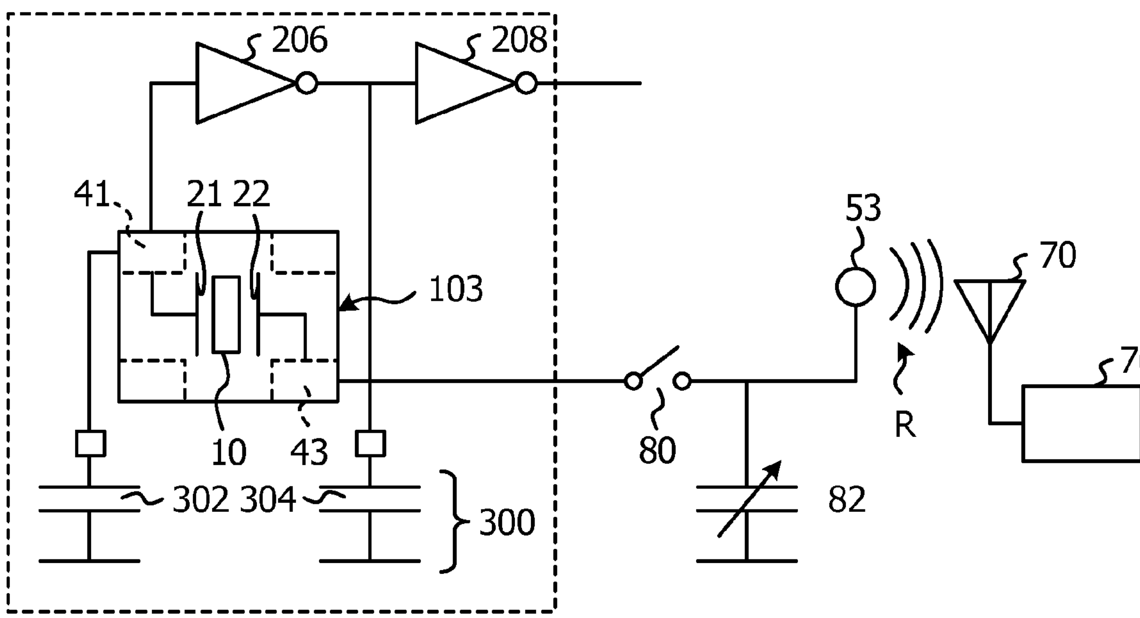
53
10
60
32
62
30
43
31
44

FIG. 7



CRYSTAL UNIT AND METHOD OF MEASURING CHARACTERISTICS OF THE CRYSTAL UNIT

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2014-138722 filed on Jul. 4, 2014, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to a crystal unit and a method of measuring the characteristics of the crystal unit.

BACKGROUND

There has been known a technique in which, in a centrifugal acceleration test system of an oscillation unit using a crystal unit, an electromagnetic wave is broadcast at an oscillation frequency of the oscillation unit from a transmitting antenna formed in the oscillation unit and is received to measure the oscillation frequency. In the centrifugal acceleration test system, the oscillation unit includes an oscillation stage (oscillation circuit) having a crystal unit, an interference amplification stage having a buffer amplifier, a transmission amplification stage having a power amplifier, and a transmitting antenna. The transmitting antenna is formed outside the oscillation stage having the crystal unit.

However, in the above-described configuration, since the transmission antenna is formed outside the crystal unit, the oscillation unit needs to include components other than the crystal unit, which may result in an increase in the size of the oscillation unit.

The following is a reference document.

[Document 1] Japanese Laid-open Patent Publication No. 2009-092544.

SUMMARY

According to an aspect of the invention, a crystal unit includes: a crystal piece; an excitation electrode configured to excite the crystal piece; a case configured to accommodate the crystal piece; an external electrode formed in the case and configured to be electrically connected to the excitation electrode; and an antenna formed in the case and configured to be electrically connected to the external electrode.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1**A and **1**B are schematic views illustrating a crystal unit **100** according to one example (Embodiment 1);

FIG. **2** is a schematic view illustrating a reception state of electromagnetic wave by a receiving antenna **70** from an antenna **50**;

FIG. **3** is a schematic view illustrating one example of a circuit configuration incorporating the crystal unit **100**;

FIG. **4** is a view illustrating one example of a mounted state of the crystal unit **100**;

FIGS. **5**A and **5**B are schematic views illustrating a crystal unit **102** according to another example (Embodiment 2);

FIGS. **6**A and **6**B are schematic views illustrating a crystal unit **103** according to another example (Embodiment 3); and

FIG. **7** is an equivalent circuit diagram of an oscillation circuit incorporating the crystal unit **103**.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments will be described in detail with reference to the accompanying drawings.

FIGS. **1**A and **1**B are schematic views illustrating a crystal unit **100** according to one example (Embodiment 1), FIG. **1**A being a top view and FIG. **1**B being a sectional view taken along the line B-B in FIG. **1**A. In FIG. **1**A, a cover of a case **30** is not illustrated to allow the interior of the crystal unit **100** to be viewed. In the following description, for the convenience of description, it is assumed that a thickness direction of a crystal piece **10** (a vertical direction in FIG. **1**B) is a vertical direction and a side in which the cover of the case **300** is present is an "upper side." However, a direction of a mounted state of the crystal unit **100** is optional. In addition, as used herein, the term an "outer surface" refers to a surface exposed to the outside of the case **30** and the term an "inner surface" refers to a surface exposed to the inner space of the case **30**.

The crystal unit **100** includes a crystal piece **10**, an excitation electrode **20**, a case **30**, external electrodes **41** to **44** and an antenna **50**. The crystal unit **100** is of a surface mounting type as illustrated in FIGS. **1**A and **1**B.

The crystal piece **10** may be, for example, an AT cut synthetic crystal substrate. The crystal piece **10** may be supported in a cantilever structure to the case **30**. In the example illustrated in FIGS. **1**A and **1**B, the crystal piece **10** is supported in the cantilever structure on a dam portion **31** of the case **30**.

The excitation electrode **20** excites the crystal piece **10**. The excitation electrode **10** includes an upper excitation electrode formed on the upper surface of the crystal piece **10** and a lower excitation electrode **22** formed on the lower surface of the crystal piece **10**. The excitation electrode **20** excites the crystal piece **10** using a potential difference between the upper excitation electrode **21** and the lower excitation electrode **22**. The excitation electrode **20** may be made of gold, silver, or aluminum.

The case **30** accommodates the crystal piece **10**. The case **30** is made of, for example, ceramic material. The case **30** includes a cover **34** (see, e.g., FIG. **2**) and air-tightly seals the crystal piece **10** in its internal space. For example, the internal space of the case **30** is vacuous or filled with dry nitrogen and is sealed with the cover **34**. The cover **34** may be a metal plate or a ceramic plate.

The external electrodes **41** to **44** are formed in the case **30**. In the example illustrated in FIGS. **1**A and **1**B, the external electrodes **41** to **44** are formed on the outer surface of the bottom of the case **30**. The external electrodes **41** and **43** are electrically connected to the upper excitation electrode **21** and the lower excitation electrode **22**, respectively. In the example illustrated in FIGS. **1**A and **1**B, the external electrode **41** is electrically connected to the upper excitation electrode **21** via a conductor pattern **45** formed on an inner layer of the case **30** and a conductor pattern **47** formed on the upper surface of the crystal piece **10**. The conductor pattern **45** has both ends exposed from the inner layer to the surface of the case **30**, with one end electrically connected to the external electrode **41** and the other end electrically connected to the conductor pattern **47** by a conductive adhesive **49**.

Similarly, the external electrode **43** is electrically connected to the lower excitation electrode **22** via a conductor pattern **46** formed on the inner layer of the case **30** and a conductor pattern **48** formed on the lower surface of the crystal piece **10**. The conductor pattern **46** has both ends exposed from the inner layer to the surface of the case **30**, with one end electrically connected to the external electrode **43** and the other end electrically connected to the conductor pattern **48** by the conductive adhesive **49**. The conductive adhesive **49** is formed at an edge of the crystal piece **10** (an edge of a cantilever-supported side). In the example illustrated in FIGS. **1**A and **1**B, the external electrodes **42** and **44** may be omitted.

The antenna **50** is formed in the case **30**. In the example illustrated in FIGS. **1**A and **1**B, the antenna **50** is formed on the inner layer of the case **30**, as in the conductor patterns **45** and **46**. For example, the antenna **50** is formed by firing a conductor on a ceramic material forming the case **30**. The shape of the antenna **50** is optional. In the example illustrated in FIGS. **1**A and **1**B, the antenna **50** extends linearly. As illustrated in FIG. **1**A, the antenna **50** may have a bent portion such that its entire length becomes a predetermined length. The predetermined length may be determined depending on the oscillation frequency (designed value) of the crystal piece **10**. In the example illustrated in FIGS. **1**A and **1**B, the antenna **50** has one end electrically connected to the conductor pattern **46** on the dam **31** and the other end which is a free end. The antenna **50** may extend in the same plane over the entire length or may extend in a partial section in a vertical direction or in an oblique and vertical direction.

In operation of the crystal unit **100**, when the crystal piece **10** is oscillated at a certain frequency, an electric field (standing wave) is generated in the antenna **50** at that frequency. Accordingly, as schematically indicated by R in FIG. **2**, an electromagnetic wave having a frequency corresponding to the oscillation frequency of the crystal piece **10** is radiated from the antenna **50**. Accordingly, as schematically illustrated in FIG. **2**, by forming a receiving antenna **70** outside the crystal unit **100** and receiving the electromagnetic wave in the receiving antenna **70**, it becomes possible to measure the oscillation frequency of the crystal unit **100**.

With the crystal unit **100** illustrated in FIGS. **1**A and **1**B, since the antenna **50** is installed in the crystal unit **100**, it becomes possible to measure the oscillation frequency of the crystal unit **100** externally. Thus, for example, for the crystal unit **100** in the mounted state, it is possible to measure the oscillation frequency. As the oscillation frequency may be measured, it becomes possible to make comparison of relative characteristics with non-defective products. In addition, since the antenna **50** is installed in the case **30**, it becomes possible to make the crystal unit **100** compact as compared to a case where the antenna is externally attached to the outside of the case **30**.

In the example illustrated in FIGS. **1**A and **1**B, the antenna **50** is formed in the aspect of electrical connection to the lower excitation electrode **22**. Instead, the antenna **50** may be formed in the aspect of electrical connection to the upper excitation electrode **21**. Alternatively, in addition to the antenna **50**, a second antenna (not illustrated) may be formed in the aspect of electrical connection to the upper excitation electrode **21**.

FIG. **3** is a schematic view illustrating one example of a circuit configuration incorporating the crystal unit **100**.

In the example illustrated in FIG. **3**, the crystal unit **100** is connected to an IC (Integrated Circuit) **200**. That is, the external electrodes **41** and **43** of the crystal unit **100** are respectively connected to an input terminal **202** and an output terminal **204** of the IC **200**. The crystal unit **100** generates a clock used in the IC **200**. The IC **200** includes an inverting amplifier **206** and an output buffer **208**. A signal input to the input terminal **202** is inverted and amplified by the inverting amplifier **206**. The inverted and amplified signal is input to the output buffer **208** and is supplied to the upper excitation electrode **21** via the external electrode **43**.

Matching capacitors **300** are connected to the crystal unit **100**. More specifically, a first capacitor **302** is connected between the external electrode **41** of the crystal unit **100** and a ground, and a second capacitor **304** is connected between the external electrode **43** of the crystal unit **100** and the ground. With regard to the IC **200**, for example, terminal internal capacitance, stray capacitance of wiring patterns of a mounting substrate, and resistance limiting a current flown into the crystal unit **100** are not illustrated in FIG. **3**. The matching capacitors **300** are formed to adjust the oscillation frequency of the crystal unit **100** such that the oscillation frequency becomes a desired value (designed value) when the total capacitance (load capacitance) including all circuit capacitance ranging from the crystal unit **100** to the IC **200** is assumed as a load. In FIG. **3**, a range enclosed by a dotted line forms an oscillation circuit.

The IC **200** may include terminals **220** and **222** for monitoring the oscillation circuit. However, these terminals **220** and **222** may be omitted. This is because the oscillation frequency of the crystal unit **100** may be measured (monitored) as the crystal unit **100** includes the antenna **50**, as described above. Accordingly, the crystal unit **100** illustrated in FIGS. **1**A and **1**B eliminates a need to form the terminals **220** and **222**, thereby achieving a simplification of the IC **200**.

In addition, in the input side and output side of the crystal unit **100**, since the signal is amplified by the inverting amplifier **206**, the output side of the crystal unit **100** has the larger amplitude of the signal than the input side thereof. Accordingly, the antenna **50** may be connected to the output side of the crystal unit **100**, as illustrated in FIG. **3**. In the example illustrated in FIG. **3**, the upper excitation electrode **21** and the lower excitation electrode **22** may be reversed.

FIG. **4** is a view illustrating one example of a mounted state of the crystal unit **100**.

As illustrated in FIG. **4**, the crystal unit **100** may be mounted on a substrate **90**. In the example illustrated in FIG. **4**, a peripheral component **92** is mounted near the crystal unit **100**.

In the meantime, in recent years, compactness and high density mounting of parts and modules have been progressed to meet the demands for a device downsizing. Compactness (for example, 3.2×2.5 mm, 2.5×2.0 mm and 2.0×1.6 mm) of crystal units serving as clock sources has been also unexceptionally progressed. Under such circumstances, when the functional failure of a device is deemed to have occurred due to the abnormality of a crystal unit, it is useful to be able to measure electrical characteristics of the crystal unit with it mounted in the device. This is because taking out only the crystal unit mounted with high density for measurement is accompanied by a risk of destroying peripheral components when removing the crystal unit.

In this regard, in the mounted state of the crystal unit, it may be possible to make probe measurement of high impedance. However, with recent trend of downsizing, there may be a case where the IC **200** does not have a terminal which may verify an oscillation state (see, e.g., the terminals **220** and **222** in FIG. **3**) and terminals are hidden in the back side of an IC package by BGA (Ball Grid Array). In addition, there may be a case where no probing point is present, such as, for example, the matching capacitors **300** being incorporated in the IC **200**, and provision of terminals in the backside of the crystal unit **100**. In addition, with the progress of a high density mounting, there may be a case where there is no site that the probe **78** contacts physically, as schematically illustrated in FIG. **4**. In addition, even when a probing point is present, if the margin of the design of an oscillation circuit is insufficient, there may be a case where an oscillation state is changed (from oscillation to non-oscillation and vice versa) by only a few pF capacitance applied by the probe **78**, thereby making a correct measurement impossible.

In this regard, with the crystal unit **100** illustrated in FIGS. **1**A and **1**B, since the crystal unit **100** includes the antenna as described above, the oscillation frequency of the crystal unit **100** may be measured with high precision even when probe measurement is impossible or difficult.

FIGS. **5**A and **5**B are schematic sectional views illustrating a crystal unit **102** according to one example (Embodiment 2), FIG. **5**A being a sectional view and FIG. **5**B being a side view when viewed in the right side of FIG. **5**A.

The crystal unit **102** according to Embodiment 2 is different from the crystal unit **100** according to Embodiment 1 in that an antenna **52** is used for the antenna **50**. Other configurations of Embodiment 2 may be substantially the same as the configurations of Embodiment 1.

The antenna **52** is installed on the outer surface of the case **30**. The antenna **52** may be formed on one side of the case **30** or may be formed over a plurality of sides of the case **30**. For example, the antenna **52** may be formed by firing a conductor on a ceramic material that forms the case **30**. In the example illustrated in FIGS. **5**A and **5**B, the antenna **52** is formed on one side of the case **30**. The shape of the antenna **52** is optional. In the example illustrated in FIGS. **5**A and **5**B, the antenna **52** extends linearly. As illustrated in FIG. **5**B, the antenna **52** may have a bent portion such that its entire length becomes a predetermined length. The predetermined length may be determined depending on the oscillation frequency (designed value) of the crystal piece **10**. In the example illustrated in FIGS. **5**A and **5**B, the antenna **52** has one end electrically connected to the conductor pattern **46** (or the lower excitation electrode **22**) and the other end which is a free end.

The crystal unit **102** illustrated in FIGS. **5**A and **5**B illustrates the same effects as the crystal unit **100** illustrated in FIGS. **1**A and **1**B.

In the example illustrated in FIGS. **5**A and **5**B, the antenna **52** is installed on the outer surface of the side of the case **30**. However, the antenna **52** may be installed on the outer surface of the bottom of the case **30** or may be installed on the outer surface of the cover **34**. In addition, the antenna **52** needs not be installed on the outer surface of the case **30** but may be installed on the inner layer or the inner surface of the case, as in the antenna **50**. In this way, the antenna **52** may be installed at any place.

In the example illustrated in FIGS. **5**A and **5**B, the antenna **52** is formed in the aspect of electrical connection to the lower excitation electrode **22**. Instead, the antenna **52** may be formed in the aspect of electrical connection to the upper excitation electrode **21**. Alternatively, in addition to the antenna **52**, a second antenna (not illustrated) may be formed in the aspect of electrical connection to the upper excitation electrode **21**.

FIGS. **6**A and **6**B are schematic views illustrating a crystal unit **103** according to another example (Embodiment 3), FIG. **6**A being a top view and FIG. **6**B being a sectional view taken along line C-C in FIG. **6**A. In FIGS. **6**A and **6**B, a sorter **80** and a variable capacitor **82** are schematically illustrated. In FIG. **6**A, only the sorter **80** is schematically indicated by a broken line. FIG. **7** is an equivalent circuit diagram of an oscillation circuit incorporating the crystal unit **103**.

The crystal unit **103** according to Embodiment 3 is different from the crystal unit **100** according to Embodiment 1 in that an antenna **53** is used for the antenna **50**, and the sorter **80** and the variable capacitor **82** are formed. Other configurations of Embodiment 3 may be substantially the same as the configurations of Embodiment 1. In FIGS. **6**A and **6**B, substantially the same elements as those in FIGS. **1**A and **1**B are denoted by the same reference numerals and explanation of which will not be repeated.

The crystal unit **103** includes a crystal piece **10**, an excitation electrode **20**, a case **30**, a seal portion (one example of an insulating portion) **32**, external electrodes **41** to **44** (not partially illustrated), an antenna **53**, a sorter (one example of a conductor) **80**, and a variable capacitor **82**.

The seal portion **32** is formed between the antenna **53** and the external electrode **43**, and makes electrical isolation between the antenna **53** and the external electrode **43**. In the example illustrated in FIGS. **6**A and **6**B, the seal portion **32** is formed on the circumference of the cover **34** in which the antenna **53** is formed. The seal portion **32** is formed to increase sealability of the cover **34** on the circumference (airtightness of the case **30**). The seal portion **32** is made of, for example, insulating material such as, for example, glass. In the example illustrated in FIGS. **6**A and **6**B, the external electrode **43** is connected to an upper electrode **60** via a conductor pattern **62**. The conductor pattern **62** is formed on the outer surface of the side of the case **30**, and the upper electrode **60** is formed on the outer surface of the top of the case **30**. Accordingly, in the example illustrated in FIGS. **6**A and **6**B, as the seal portion **32** is formed between the upper electrode **60** and the antenna **53**, the seal portion **32** makes an electrical isolation between the antenna **53** and the external electrode **43**.

The antenna **53** is formed on the outer surface of the cover **34**. For example, the antenna **53** is formed by firing a conductor on a ceramic material that forms the cover **34**. The shape of the antenna **53** is optional. In the example illustrated in FIGS. **6**A and **6**B, the antenna **53** extends linearly. As illustrated in FIG. **6**A, the antenna **53** may have a bent portion such that its entire length becomes a predetermined length. The predetermined length may be determined depending on the oscillation frequency (designed value) of the crystal piece **10**. In the example illustrated in FIGS. **6**A and **6**B, the antenna **53** has one end extending to the vicinity of the upper electrode **60** (but being electrically isolated from the upper electrode **60**) and the other end which is a free end.

The sorter **80** may be attached to the case **30**. In the example illustrated in FIGS. **6**A and **6**B, the sorter **80** may be attached between the antenna **53** and the upper electrode **60** in the case **30**. An aspect of attachment of the shorter **80** to the case **30** is optional. For example, the sorter **80** may be attached via, for example, a fastener or may be simply mounted. The sorter **80** is formed by a conductor and its resistance may be substantially zero (0). The sorter **80** may have a shape of a jumper element (jumper chip/jumper lead). The sorter **80** electrically connects the antenna **53** and the external electrode **43** under a state where the sorter **80** is attached to the case **30**. In the example illustrated in FIGS. **6**A and **6**B, under the state where the sorter **80** is attached to the case **30**, the sorter **80** electrically connects the antenna **53** and the external electrode **43** by making a connection between the antenna **53** and the upper electrode **60**. As illustrated in FIG. **7**, the sorter **80** acts as a switch as a circuit and the state of attachment of the shorter **80** to the case **30** corresponds to a state where the switch is closed.

The variable capacitor **82** has one end connected between the shorter **80** and the antenna **53** and the other end connected to a ground G. That is, the variable capacitor **82** is formed in a line **84** connecting the sorter **80** to the ground G. Under the state where the sorter **80** is attached to the case **30**, as illustrated in FIG. **7**, the variable capacitor **82** is connected in parallel to the second capacitor **304** of the matching capacitors **300** between the antenna **53** and the external electrode **43**. At this time, when the capacitance of the variable capacitor **82** is varied, the frequency of an output signal of the inverting amplifier **206** is varied, and the frequency of an electromagnetic wave transmitted from the antenna **53** is also varied.

The crystal unit **103** illustrated in FIGS. **6**A and **6**B illustrates the same effects as the crystal unit **103** illustrated in FIGS. **1**A and **1**B. In addition, with the crystal unit **103**, since the electrical isolation between the antenna **53** and the external electrode **43** is made by the seal portion **32** under a state where the sorter **80** is not attached to the case **30**, it is possible to reduce an effect of an external noise which may be received via the antenna **53**. That is, the antenna **53** may serve as a receiving antenna, which means that the external noise received from the antenna **53** may have an effect on the operation of the crystal unit **103**. In this regard, with the crystal unit **103**, by attaching the sorter **80** to the case **30** only when measuring the oscillation frequency of the crystal unit **103**, it is possible to eliminate the effect of the antenna **53** on the operation of the crystal unit **103** for other cases.

In the example illustrated in FIGS. **6**A and **6**B, the antenna **53** is formed on the outer surface of the cover **34**. However, the antenna **53** may be formed on the inner layer or inner surface of the cover **34** in such a manner that the antenna **53** is exposed to the outer surface of the cover **34** in an attachment portion of the sorter **80**. In addition, the antenna **53** may be installed on the outer surface of the side of the case **30** or may be install on the outer surface of the bottom of the case **30**. In addition, the antenna **53** may be formed by the cover **34** itself. In addition, in the example illustrated in FIGS. **6**A and **6**B, although the conductor pattern **62** is formed on the outer surface of the case, it may be formed on the inner layer of the case **30**.

In the example illustrated in FIGS. **6**A and **6**B, the antenna **53** is formed in the aspect of electrical connection to the lower excitation electrode **22**. Instead, the antenna **53** may be formed in the aspect of electrical connection to the upper excitation electrode **21**. Alternatively, in addition to the antenna **53**, a second antenna (not illustrated) may be formed in the aspect of electrical connection to the upper excitation electrode **21**.

In the example illustrated in FIGS. **6**A and **6**B, the variable capacitor **82** may be formed. However, the variable capacitor **82** may also be omitted as well. The meaning of the variable capacitor **82** will be described in connection with an oscillation frequency measuring method as described below.

Next, a method of measuring the oscillation frequency of the crystal unit **103** illustrated in FIGS. **6**A and **6**B will be described.

In measurement of the oscillation frequency, first, the sorter **80** is attached to the case **30** and the antenna **53** and the external electrode **43** are electrically connected. The crystal unit **103** enters an operation state. The receiving antenna **70** (FIG. **7**) is installed and an electromagnetic wave is received from the antenna **53**. A signal according to the electromagnetic wave received in the receiving antenna **70** is processed in a signal processing apparatus **76** and the oscillation frequency of the crystal unit **103** is measured. For example, the signal processing apparatus **76** outputs the peak frequency of the received signal by performing a process such as, for example, FFT (Fast Fourier Transform).

At this time, if a plurality of peak frequencies exists near a designed value of the oscillation frequency of the crystal unit **103** due to a noise effect, the capacitance of the variable capacitor **82** is changed. The capacitance of the variable capacitor **82** may be changed manually or may be changed according to a command from the signal processing apparatus **76** (a command generated by executing a program). As described above, when the capacitance of the variable capacitor **82** is changed, the frequency of the output signal of the inverting amplifier **206** is changed and the frequency of the electromagnetic wave transmitted from the antenna **53** is also changed. On the other hand, with regard to noise, even when the capacitance of the variable capacitor **82** is changed, a frequency is not remarkably changed.

This is used to select a peak whose frequency is changed, of a plurality of peaks obtained as a result of FFT when the capacitance of the variable capacitor **82** is changed, as an object to be measured. This selection may be achieved either manually (by naked eyes of an examiner) or by the signal processing apparatus **76**. When the peak of the object to be measured is selected, the capacitance of the variable capacitor **82** is changed to zero (0) (or the variable capacitor **82** is removed) and a frequency according to the peak of the object to be measured is determined as the oscillation frequency of the crystal unit **103**. This determination may be achieved by an examiner or the signal processing apparatus **76**.

In this way, since the crystal unit **103** illustrated in FIGS. **6**A and **6**B includes the variable capacitor **82**, even when a plurality of peak frequencies exists near the designed value of the oscillation frequency of the crystal unit **103**, it is possible to measure the oscillation frequency of the crystal unit **103** with a high precision. This is particularly useful when the electromagnetic wave transmitted from the antenna **53** is weak. In other words, it is possible to measure the oscillation frequency of the crystal unit **103** with high precision without high performance of the antenna **53**.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a illustrating of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A crystal unit comprising:
- a crystal piece;
- an excitation electrode configured to excite the crystal piece;
- a case configured to accommodate the crystal piece;
- an external electrode formed in the case and configured to be electrically connected to the excitation electrode; and
- an antenna formed in the case and configured to be electrically connected to the external electrode,
- wherein the antenna is formed on an inner layer or a surface of the case.

2. The crystal unit according to claim **1**, further comprising:

an insulating portion formed between the antenna and the external electrode and configured to make an electrical isolation between the antenna and the external electrode; and

a conductor attachable to the case and configured to electrically connect the antenna and the external electrode in a state where the conductor is attached to the case.

3. The crystal unit according to claim **2**, further comprising:

a variable capacitor having one end connected to the conductor and the other end connected to a ground.

4. The crystal unit according to claim **1**, wherein

the case includes a cover.

5. The crystal unit according to claim **1**,

wherein, when the crystal unit is connected to an IC (Integrated Circuit), the external electrode includes a first external electrode connected to an input side of an amplifier in the IC, and a second external electrode connected to an output side of the amplifier in the IC, and

wherein the antenna is electrically connected to the second external electrode.

6. The crystal unit according to claim **1**, wherein

the crystal unit is of a surface mounting type.

7. A method of measuring characteristics of a crystal unit, comprising:

disposing a conductor on an insulating portion between an antenna and an excitation electrode which excites a crystal piece in the crystal unit;

receiving an electromagnetic wave transmitted from the antenna when the crystal piece is excited;

analyzing a frequency of the received electromagnetic wave; and

changing capacitance of a variable capacitor having one end connected to the conductor and the other end connected to a ground,

wherein the analyzing a frequency of the received electromagnetic wave includes determining an oscillation frequency of the crystal unit based on a peak according to a peak frequency which is changed when the capacitance of the variable capacitor is changed.

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